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Photometric study of polar-ring galaxies.

III. Forming rings

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Abstract. We present the results of detailed surface photometry of NGC 3808B and NGC 6286 - two spiral galaxies with possibly forming ring-like structures rotating around major axes of the galaxies. The formation of rings in NGC 3808B and NGC 6286 being accompanied by accretion of matter on galactic disk results in some interesting gasdynamical and stellardynamical effects in these galaxies. One can note, for instance, peculiar rotation curve of NGC 3808B gaseous disk; strong infrared and Hα emission from the galaxies; bending and flaring stellar disks in both galaxies. Our observations clearly illustrate the possibility that polar-ring galaxies may be formed as a result of matter accretion from one galaxy to another.

Key words: galaxies: interactions; photometry; NGC 3808B; NGC 6286

1. Introduction

The general picture of the observed part of the Universe has been in a marked degree due to the gravitational interactions and mergings between galaxies. Observations and model calculations show that mutual interactions and accretion may change such fundamental galaxy characteristics as mass and luminosity distributions, morphological type, the rate of star formation, etc.

Galaxies with polar rings (PRGs) keep aloof among the objects which traditionally are considered as a result of interaction between galaxies. Indeed, close encounters are the reason of disturbance of the galaxy form and appearance of asymmetric structures such as bridges, tails and so on, while the merging between the galaxies is considered to result in the origin of smoothed elliptical-like objects where the remnants of merged objects are well mixed. To the contrary, "classic" PRGs (category A in Whitmore et al. 1990 (PRC)) are symmetric objects in which the remnants of interacting galaxies are not mixed but stay in a quasi-stationary state for a long time, may be comparable with Hubble time. Detailed investigation of PRGs supply the new approaches to the study of such important problems as the shape of galactic potential, the frequency of interactions and mergings, influence of interactions on global structure of galaxies, on their nuclear activity etc.

Probably the most important problem concerning PRGs is their origin. It is usually contended that the collapse of single protogalactic cloud cannot create the object with two nearly orthogonal large-scale kinematic systems and therefore in the history of such objects some second event (for instance, interaction or merging) has occured (Schweizer et al. 1983, Whitmore et al. 1987). From the other side, recent simulations by Curir & Diaferio (1994) seem to indicate that a single dissipationless collapse of rotating triaxial system can produce misaligned spins.

Here we give the results of new observations of two candidates to PRGs from the PRC which obviously demonstrate the possibility of polar-ring galaxy formation as a result of interaction between galaxies.

Throught this paper the value $H_0 = 75$ km/s/Mpc is adopted.

2. Observations and reductions

The photometric observations of galaxies were carried out in 1992 and 1994 in the prime focus of the 6-m telescope of the Special Astrophysical Observatory of Russian Academy of Sciences. The photon collector was virtual phase CCD of 520×580 pixels, each 18×24 μm (0.15×0.2″) (Borisenko et al.1991). Reimaged optics, that realized a field of view 4.5 × 6.9′ with angular resolution 0.53 × 0.71", was used during our observations of NGC 6286. Observations of NGC 3808 were obtained without reimaged optics − with a field of view 1.3 × 2.0′ and resolution 0.15 × 0.2". The data were acquired with standard

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Johnson B, V and Cousins R filters for NGC 6286, and with Johnson V and Cousins R, I filters for NGC 3808. Photometric calibration was accomplished using repeated observations of the $BVRI$ standard stars from Landolt (1983) and Smith et al. (1991). The seeing during our observations was about $2''$. A log of observations is given in Table 1 (extinction corrected sky brightnesses in each frame in mag arcsec^{-2} are presented in the last column of the table). Reduction of the raw CCD data was made in standard manner (for details see Paper I - Reshetnikov et al. 1994). The ESO-MIDAS package (MIDAS User Guide 1994) was used.

Table 1. Observations

Object	Data	Band-pass	Exp. (sec)	Air-mass	Sky mag.
NGC 3808	10/11.03.94	V	600	1.075	21.14
		R	300	1.079	20.66
		I	600	1.075	19.24
NGC 6286	6/7.05.92	B	1000	1.049	21.94
		V	600	1.043	21.19
		R	300	1.040	20.58

Spectral observations of the galaxies were obtained earlier at the 1.93-m telescope of the Observatoire de Haute-Provence, using the spectrograph CARELEC and the CCD TK512. For details of observations and reductions see Reshetnikov & Combes (1994) (RC).

3. Results and discussion

3.1. NGC 3808B (PRC D-19)

NGC 3808 (Arp 87, VV 300) is M 51-type interacting double system, which consists of Sc spiral with $B_t = 14.1 \pm 0.3$ (de Vaucouleurs et al. 1991, RC3) seen nearly face-on and a companion located at the end of spiral arm of the main galaxy and seen edge-on. In what follows we shall refer to the main galaxy as NGC 3808A and the companion as NGC 3808B. The distance to the system is D $= 93$ Mpc (RC) and the angular separation between companions is about 1.1' (30 kpc). Our unpublished observations with 6-m telescope show that a radial velocity difference between two galaxies is only 33 km/s.

As one can see in Fig.1 where a contrast copy from the "Atlas of Peculiar Galaxies" (Arp 1966) is given, the spiral arm of the main galaxy is not only drawn out to the companion but twines it forming an unrolled spiral. For this reason Schweizer (1986) has supposed that in the case of NGC 3808B we observe the formation of polar ring as a result of mass transfer from the nearby galaxy. This suggestion is confirmed by spectral observations which have shown that the main body of the galaxy rotates around minor axis whereas the matter of twined arm moves around the major axis of the galaxy as in classic PRGs (Reshetnikov & Yakovleva 1990).

Fig. 1. Reproduction of NGC3808 from the Atlas of Peculiar Galaxies by Arp (1966). North is at the top, east to the left

3.1.1. Photometric characteristics

Global photometric parameters of NGC 3808B are summarized in Table 2 (the value of B_t in the table was derived from our V_t magnitude and colour index from Gavazzi et al. (1991): $B - V = +0.65$).

There are some published results of photometric observations of NGC 3808B. Tomov (1978) has found $V = 14.27$ for the 54" aperture which covers almost whole galaxy. This value is more bright than that found by us ($V_t = 14.39$) probably because of getting in the aperture the star, located to SW from the galaxy.

Gavazzi et al. (1991) give the results of photoelectric observations of NGC 3808B with three various apertures. The mean difference between these values and our measurements for the same apertures is $-0.05 \pm 0.02\,(\sigma)$. In the work of Gavazzi & Randone (1994) the apparent magnitude in the V band within the elliptical isophote of 25 mag arcsec^{-2} is given: $V_{25} = 14.61$. Taking in mind the mean difference between their V_{25} and total magnitudes in RC3 ($+0.3 \pm 0.2$) we make the conclusion about good agreement between our V_t value and the data of Gavazzi & Randone (1994).

The isophotes of NGC 3808B in the V band are given in Fig.2. The main body of the galaxy is viewed practically edge-on. The twined arm become apparent as "swelling" of isophotes to NW and SE from the main body. Outside the main body the arm does not end but goes to NW from its edge as far as ≈40" (18 kpc). In Fig.2 one can see faint ($V = 18.7$) galaxy projected on the NE edge of NGC 3808B. We think this galaxy is background one seen here by chance. However, it may be gravitationally bound with NGC 3808A,B but because of its non-distorted structure it is located sufficiently far from the pair and does not participate in strong gravitational interaction between A and B galaxies.

Table 2. General characteristics

	NGC 3808B	NGC 6286
D (Mpc) [RC]	93.0	76.5
$A_g(B)$ [RC3]	0.00	0.02
B_t ($\pm$0.10)	15.04	14.2
$(B-V)_t$	+0.65[1]	+0.75 $\pm$ 0.05
$(V-R)_t$	+0.48 $\pm$ 0.03	+0.50 $\pm$ 0.03
$(R-I)_t$	+0.46 $\pm$ 0.03	
a ($\mu_B = 26$)	0.77' (20.7 kpc)	1.68' (37.5 kpc)
b/a ($\mu_B = 26$)	0.36:	0.36:
μ_0	18.5(V)	20.4 (B)[2]
h	3.9" (1.8 kpc)	6.6" (2.5 kpc)[2]
z_0	2.2" (1.0 kpc)[3]	3.8" (1.4 kpc)[3]
V_{max} (km/s)	120$\pm$10	
Possible forming ring :		
M	-18(V)	-18.4(B)
$B-V$		+0.5:
$V-R$	+0.4:	+0.3:
$R-I$	+0.4:	
V_{max}(km/s)	120	100:
Ring-to-central galaxy ratio	0.1(V)	0.2(B)

(1) Gavazzi et al. (1991)
(2) Value determined from the equivalent profile
(3) Minimum value observed within galactic disk

Fig. 2. Isophotal contour image of NGC 3808B in the V passband. The faintest contour is 26.0 mag arcsec^{-2}, isophotes step - $0.^{m}75$. The arrow indicates a length of 60"

3.1.2. Host galaxy

Observed colour indexes of NGC 3808B listed in Table 2 correspond to the normal Sab-Sb galaxy. After reducing for redshift and inclination made in accordance with RC3 recommendations the colour indexes ($B-V \approx$+0.5, $V-R \approx$+0.4) correspond to Sc-Scd galaxy (Buta et al. 1994, Buta & Williams 1995).

The photometric profile along the major axis (P.A. = 55^o) is shown in Fig.3a. As one can see, the surface brightness distribution is nearly exponential (note the contribution of star and faint galaxy in SW and NE parts of the profile correspondingly at r $\geq$ 20"). Representing the profile by exponential law we find that the parameters of the brightness distribution for r $\leq$ 20" are h = 3.9" $\pm$ 0.35" (exponential scale-length) and $\mu_0(V) = 18.5 \pm 0.2$ (central surface brightness). After transforming $\mu_0(V)$ value to $\mu_0(R)$ (in the Cousins system) by assuming that $V-R$ = 0.5 we have compared the disk parameters of NGC 3808B with those for large sample of interacting galaxies studied in Reshetnikov et al. (1993b). The photometric parameters of NGC 3808B are found to be typical for extremly interacting galaxies (Figs.13 and 15 in cited paper).

Fig. 3. (a) Luminosity profile along the major axis of NGC 3808B in the V passband. (b) Distribution of radial velocities along the major axis of the galaxy

Fig. 4. (a) Photometric profile of NGC 3808B along the minor axis. (b) Radial velocities distribution along the minor axis of the galaxy

It is well known that in normal spirals the z-structure of stellar disks is well represented by the model of a locally isothermal, self-gravitating stellar sheet with scale-height z_0 independent on galactocentric distance (van der Kruit & Searle 1981). The disks of non-dwarf spiral galaxies can be characterized by the value of $z_0 = 0.7 \pm 0.2$ kpc (van der Kruit 1989). The distributions of z_0 values along the disk of NGC 3808B in three passbands are given in Fig.5. To eliminate the influence of twined arm and surrounding envelope, only the most bright inner parts of profiles parallel to the minor axis were used for estimating the scale-height values of the disk. As one can see, these values increase with moving away from the center of galaxy (at the edge of the disk z_0 is approximately twice as large as at the center). Such stellar disk structure is expected for the galaxies subjected to strong external accretion or merging (Toth & Ostriker 1992, Quinn et al. 1993).

Fig. 5. Scale-height distributions for NGC 3808B as a function of radius along the major axis. Circles represent the data in the V band, crosses - R, rectangles - I

The rotation curve of NGC 3808B along the major axis constructed using the data of emission lines Hα and [N II] is shown in Fig.3b according to RC. It is seen that the galaxy demonstrates very peculiar kinematics: the kinematic center of the galaxy is shifted from the photomteric one by approximately 0.7" (0.3 kpc) to NE; after reaching the maximum value ($\mathrm{V}_{\max} = 120\pm10$ km/s) at r $\approx$ 3" the radial velocities show rapid decrease to the value nearly equal to the systematic velocity. According to classification of rotation curves for interacting galaxies suggested by Keel (1993) (Fig.2 in that paper) the rotation curve of NGC 3808B belongs to the group DIST (disturbed).

In Fig.6 the solid line represents the rotation curve of the galaxy averaged relative to the center and polinomially smoothed. Evidently it cannot reflect a real mass distribution in the galaxy but is a result of combined influence of gravitational disturbance from massive companion (NGC 3808A) and matter accretion from that to NGC 3808B on the gaseous disk of the latter. Let us find what rotation curve NGC 3808B would have if it was not a member of interacting pair. To do this we have approximated the inner part (r $\leq$ 2.5") of the observed rotation curve by the model of exponential disk (Monnet & Simien 1977) with intrinsic axial ratio $b/a = 0.2$ and the value of scale-length $h = 3.9$" found earlier. The resulting curve depending besides b/a on the only free parameter (mass-to-light ratio which is f_V =3.6 in solar units) is shown in Fig.6 by dashed line. This curve is hypothetical "non-disturbed" rotation curve of the galaxy. The maximum velocity of the model rotation curve is equal to 173 km/s at r = 9" (4.1 kpc). Let us consider how it agrees with other global characteristics of the galaxy.

Fig. 6. Averaged rotation curve of the main body of NGC 3808B (solid line) and of the forming ring (short-dashed line). Dashed line represents model of "non-disturbed" rotation curve

As it follows from integral colour indexes and surface brightness distribution, NGC 3808B belongs to Sc-Scd galaxies. Using the data on 207 spiral galaxies compiled by Corradi & Capaccipli (1991), Reshetnikov (1994) found the following dependence between numerical Hubble stage index (T) and maximum rotation velocity: $\mathrm{V}_{\max}\,(\mathrm{km/s}) = 292 - 22.7T$. From this equation the value $\mathrm{V}_{\max} \approx 156 - 179$ km/s should be expected for NGC 3808B. The value of $\mathrm{V}_{\max}$ for "non-disturbed" rotation curve falls into this interval. The Tully-Fisher relationship in the B band according to Rubin et al. (1985) shows that normal Sc galaxy with the luminosity of NGC 3808B must have the maximum rotational velocity of $160-165$ km/s which is also in agreement with our model rotation curve. The use of the Tully-Fisher relationship in the I band according to Byun (1992) leads to better agreement - $\mathrm{V}_{\max} \approx 170$ km/s.

Comparing observed and "non-disturbed" rotation curves one can conclude that strong gravitational disturbance together with mass transfer to NGC 3808B results in observed displacement of the global maximum of rotation curve to the center (approximately by 6" = 2.7 kpc) and in "braking" (approximately by 50 km/s) of the gaseous disk of the galaxy. The latter is in agreement with the conclusion of Reshetnikov (1994) who found that spiral galaxies in strongly interacting systems tend to have lower observational rotational velocities than the same field galaxies.

Interaction between gaseous disk of the galaxy and accreting gas of twined spiral arm may lead (besides of disturbance of the velocity field) to intensification of star-

forming activity in NGC 3808B. Indeed, as it was pointed out in RC, NGC 3808B shows both strong emission lines in circumnuclear regions (within rectangular aperture 2.5" $\times$ 2.3", centered on the nucleus, the equivalent width of Hα emission line and the observed Hα luminosity are found to be W(Hα) $=$ 39 Å, L(Hα) $= 2 \times 10^{40}$ erg/s) and intense far-infrared radiation (L(FIR) $= 4.4 \times 10^{10} L_{\odot}$). For a sample of interacting galaxies Keel (1993) has found a correlation between Hα equivalent width and greatest observed deviation from a symmetric rotation curve when normalized to the peak rotation velocity. Comparing the data for NGC 3808B with Fig.5 in Keel (1993) we find that the parameters of the galaxy are in agreement with the dependence presented in that paper.

To consider the problem of emission mechanism in the nucleus of NGC 3808B we compiled the results of spectral observations of the galaxy from Keel et al. (1985) and RC. The reddening was taken into account by standard way adopting I(Hα)/I(Hβ) = 3.1 (Veilleux & Osterbrock 1987). The value of absorption in the direction of the nucleus was found to be $3.^{\rm m}4$ in the B band. It turned out that in standard classification diagrams ([O III]λ5007/Hβ vs. [N II]λ6583/Hα and [O I]λ6300/Hα, one of these is given in Fig.7) reddening-corrected line ratios are located near the boundary between AGNs (Seyferts and LINERs) and HII-like objects (Veilleux & Osterbrock 1987). We think that the nucleus of NGC 3808B may be an example of masking of active nucleus by circumnuclear burst of star formation - the situation discussed earlier by Keel et al. (1985). (Note that the reddening-corrected Hα luminosity of the central region of the galaxy is more than 10^{41} erg/s.) For the final decision of the problem of the nature of NGC 3808B nucleus spectral observations with high (better than 1") spatial resolution are needed.

Fig. 7. Reddening-corrected [OIII]λ5007/Hβ vs. [OI]λ6300/Hα intensity ratio for the nucleus of NGC 3808B (circle). Solid curve divides AGNs from HII region-like objects according to Veilleux & Osterbrock (1987)

3.1.3. Forming ring

The photometric profile of NGC 3808B along the minor axis is shown in Fig.4a. Just for r $\approx$ 5" from the nucleus surface brightness distribution becomes more flat than that usually observed in normal edge-on spirals. This feature may be explaned by the contribution to the observed profile of the most bright and contrast part of spiral arm of NGC 3808A drawn out to NGC 3808B and twined the latter (see Fig.1). Surface brightness of this pseudo-ring structure crossing the central region of NGC 3808B along its minor axis is $\mu(V) \approx 23 - 24$.

The dependence on distance from the nucleus of radial velocities along the minor axis found in RC from measurements of Hα and [N II] lines is given in Fig.4b. As one can see, the rotation curve of the forming ring represents almost a straight line (see also Fig.6). The slope of the rotation curve is equal to 13 km/s/arcsec or 29 km/s/kpc, the maximum velocity is close to that observed in the main galaxy (Fig.6) (such a feature is typical for "classic" PRGs). The straight character probably suggests that a relatively narrow ring has been formed in circumpolar plane of the galaxy. The possibility of forming such ring structures accumulating the part of accreting matter has been shown by Weil & Hernquist (1993) and Sotnikova (1996) in course of numerical simulations. The gas of the ring interacting with that of the galaxy disk settles on it. On the other hand there is a permanent supply of the ring with the matter transfered from NGC 3808A. Stopping of accretion seems to result in prompt disappearence of the ring.

The maximum observed rotational velocity in the forming ring (as well as in the main body of the galaxy) is approximately equal to 120 km/s. Its total (after account for all parts twined around NGC 3808B) observed absolute luminosity is $M_V \approx -18$ that is about 10% of total galaxy luminosity. The observed colour indexes of unrolled spiral arm ($V-R$ =+0.4, $R-I$ =+0.4) are more blue than colour indexes of the main galaxy. The mean colours of the pseudo-ring indicate an age of about 10^9 years, for a solar metallicity. The matter of the pseudo-ring probably contains some dust since in the region of the spiral arm projection to the SW edge of main body the local increase of colour indexes (with $E_{V-R} = 0.^{\rm m}1 - 0.^{\rm m}15$) is observed. In addition, visual inspection of the reproduction of this system in the Atlas by Arp (1966) shows that there is some absorption in this region.

The whole projected length of twined arm ($\geq$2'=55 kpc) gives a possibility to estimate the duration of twisting of accreted matter around NGC 3808B. Adopting that a velocity of the gas is equal to maximum observed velocity in the forming ring (120 km/s), one can find that the duration of active phase of interaction with mass transfer is at least 4×10^8 years. Taking into account the projection factor this period may be increased up to 10^9 years. This value corresponds approximately to the stellar population age in the forming ring. Therefore, in this case we deal with gravitationally bound galaxies interacting over a long time but not with chance encounter. In many aspects NGC 3808 resembles interacting system NGC 7753/52 (Arp 86) in which mass transfer occurs from main galaxy to low-massive companion (Laurikainen et al. 1993, Salo & Laurikainen 1993). As in NGC 3808B, the accretion of matter to NGC 7752 results in global bursts of star formation in this galaxy. Numerical modeling shows that the compo-

nents of Arp 86 are moving in a low-eccentricity relative orbit. By analogy, we suggest that the members of NGC 3808 are also at nearly circular relative orbit favourable to mass transfer.

3.2. NGC 6286 (PRC C-51)

NGC 6285/6 (Arp 293) is an interacting double system resembling NGC 3808A,B. The mean difference between them is that in the case of NGC 6285/6 both galaxies have comparable masses. For D $=76.5$ Mpc (RC) the angular distance between galaxies (1.5') corresponds to the projected distance of 33 kpc. The radial velocity difference is not well known but seems to be no more than 200 km/s (NED[1]).

In Fig.8 the reproductions of B-band CCD image of NGC 6286 (just this galaxy is a candidate to PRG) are shown in a logarithmic scale with different contrasts for better displaying optical structure of the galaxy. The main body of NGC 6286 is seen to be a spiral galaxy viewed practically edge-on and crossed by bended dust strip (Fig.8a). In Fig.8b a diffuse semi-ring extending from SE edge of the galaxy is well notable (see also reproductions in Arp (1966) and in the PRC). In Fig.8c one can see also a weak bridge between two galaxies. The second galaxy of the pair (NGC 6285) is an early-type spiral ($T=$-1 according to RC3) with $B_t = 14.48 \pm 0.15$ (RC3).

Fig. 8. B-band image of NGC 6286 displayed at three different contrasts (in a logarithmic gray scale). The entire image is 1.85×2.1 arcmin

In RC the rotation curve of emitting gas along the minor axis of NGC 6286 is given. Though curve looks very peculiar it demonstrates possible large-scale rotation of the matter around the major axis of the galaxy. Therefore, NGC 6286 may be related (as NGC 3808B) to galaxies with forming polar rings.

3.2.1. Photometric characteristics

The main photometric parameters of NGC 6286 are collected in Table 2.

The total magnitude of the galaxy according to RC3 is $B_t = 14.06 \pm 0.18$. This value is somewhat brighter than found here ($B_t = 14.2 \pm 0.1$) but within the quoted errors this difference is insignificant. The total magnitude of NGC 6286 in R band ($R_t = 12.95$) found in this work is in good agreement with that given by Reshetnikov et al. (1993a) ($R_t = 12.89$).

The isophotes of NGC 6286 in the V passband are shown in Fig.9. As in the case of NGC 3808B, the main body of the galaxy is viewed nearly edge-on. The abovementioned dust strip results in strong isophotes distortion of the central part of the galaxy. The ring structure forming around the galaxy is well turned to the line of sight. The major axis of this possible ring is about 1.2'=27 kpc by isophote $\mu_V = 24.35$, the apparent axial ratio is $b/a \approx 0.7$.

Fig. 9. Isophotal contour image of NGC 6286 in the V passband. The faintest contour is 25.1 mag arcsec^{-2}, isophotes step - 0.^{m}75. The arrow indicates a length of 60".

3.2.2. Host galaxy

Observed colour indexes of NGC 6286 given in Table 2 correspond to the normal Sa galaxy. After standard reductions for redshift and inclination colour indexes ($B-V \approx +0.55$, $V-R \approx +0.4$) turn out to be the same as in Sbc-Sc galaxies (Buta et al. 1994, Buta & Williams 1995). However, NGC 6286 is Sb galaxy according to RC3. This discrepancy may be due to both abnormally blue colour of NGC 6286 and uncertainty in inclination correction for this nearly edge-on galaxy.

In Fig.10 the photometric profile along the major axis (P.A. $= 33^o$) in the B band is shown. Up to r $\approx \pm 30$" from the nucleus the surface brightness decreases very slowly, then falls down more rapidly. Note that the profile shows no signs of pronounced bulge in the central region of the galaxy (partly may be due to absorption of the bulge emission by dust lane projected onto the central region - see Fig.8,9). The equivalent luminosity profile of the galaxy is shown in Fig.11. As one can see, up to r$^* \approx 20$" (or $\mu(B) \approx 24$) the averaged surface brightness distribution of the galaxy is well described by exponential law with parameters $\mu_0(B) = 20.37$, $h^* = 6.6$" (dashed line in Fig.11), then the profile changes its slope and becomes more flat (see also the equivalent profile in the R passband published in Reshetnikov et al. (1993a)). This change at r$^* \approx 20$" is probably due to the contribution of ring-like structure surrounding the galaxy. Let us note also that the central surface brightness of the galactic disk is considerably brighter than canonical value $\mu_0(B) = 21.65$ (Free-

[1] The NASA/IPAC Extragalactic Database (NED) is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

man 1970). Such a property is typical for the galaxies in interacting systems (Reshetnikov et al. 1993b).

Fig. 10. Luminosity profile along the major axis of NGC 6286 in the B passband

Fig. 11. Equivalent luminosity profile of NGC 6286 in the B passband

The distribution of z_0 values along the disk of NGC 6286 is shown in Fig.12 for three passbands. To exclude the influence of ring-like structure on the estimation of scale-height of the disk we use, as in the case of NGC 3808B, only inner, most bright parts of profiles parallel to minor axis. The central region of the galaxy disturbed by the dust strip is also excluded. The values of scale-height are seen to increase while shifting from the galaxy nucleus, but not so much as in NGC 3808B: only 30%−50% for the distances from 5 kpc to 15 kpc from the nucleus.

Fig. 12. Scale-height distributions for NGC 6286 as a function of radius along the major axis. Circles represent the data in the B passband, crosses - V, rectangles - R

As well as NGC 3808B, NGC 6286 demonstrates (see RC) both strong emission lines in circumnuclear region (within rectangular aperture 2.5" × 2.3" centered to the nucleus W(Hα) = 24 Å, L(Hα) = 2.1×10^{40} erg/s), and strong IR emission ($L(\mathrm{FIR}) \approx 10^{11} L_{\odot}$). This may be a consequence of a burst of star formation induced by strong interaction with the companion. Emission-line spectrum of the nucleus is of HII-region type (RC).

3.2.3. Forming ring

Photometric profile along the minor axis of the galaxy is shown in Fig.13a. The central part of the profile follows to exact exponential law. For r ≥20" the main contribution to the observed brightness is given by the structure which we consider to be a ring forming around the galaxy. The ring is asymmetric: its SE part (semi-ring well seen in Fig.8b) has mean observed surface brightness $\mu(B)$ ≈24 while its NW part is fainter by approximately 1^{m} (as NW part we imply the nearest to NGC 6286 region of the bridge connecting two galaxies). The total magnitude of forming ring in the B band is 16.0 ± 0.3. Therefore, the contribution of the ring to the total luminosity of the galaxy is as high as 20%. Observed integral colour indexes of SE part of the ring ($B - V = +0.56 \pm 0.06$, $V - R = +0.36 \pm 0.05$) are more blue than those of main galaxy. But after correction for inclination of the galaxy to the line of sight the colour indexes of both are very close. It should be noted also that colour index $B - V$ ($\approx +0.8$) of the bridge between galaxies is somewhat redder than that of the main body of NGC 6286.

The distribution of radial velocities along the minor axis of NGC 6286 found from measurements of emission lines Hα and [NII]λ6583 in RC (where NGC 6286 is named NGC 6285 by mistake) is shown in Fig.13b. One can suppose that there are two subsystems of gas in the galaxy. One of them well seen at r ≈20" in Hα probably reflects large-scale rotation of the forming ring. From simple geometrical arguments used earlier for NGC 3808B, we have found that active phase of interaction between the galaxies being accompanied by mass transfer has been lasting no more than 5×10^8 years.

Fig. 13. (a) Photometric profile of NGC 6286 along the minor axis in the B passband. (b) Radial velocities distribution along the minor axis of the galaxy (crosses - Hα, circles - [NII]λ6583).

4. Conclusions

In this work we give the results of observations of two spiral galaxies in close interacting systems. In both systems mass transfer from one galaxy to another is observed, accreting matter forming large-scale ring-like structures rotating around the major axes of considered galaxies. Because of existence of two kinematically distinct subsystems rotating in orthogonal planes these objects - NGC 3808B and NGC 6286 - look very much like polar-ring galaxies. Both galaxies clearly illustrate the possibility that PRGs may be formed as a result of matter accretion from one galaxy to another (Schweizer et al. 1983).

In NGC 6286 the ring structure seems to be at relatively earlier stage of formation than in NGC 3808B. Ac-

creting matter in NGC 6286 probably did not have time to perform the whole revolution around the galaxy.

Both galaxies with forming rings are spirals and in both cases the diameter of observed ring is comparable (or even smaller) with diameter of the galaxy. It means that interaction has to occur between gaseous disk of the galaxy and the ring. Therefore, if mass transfer from the companion stops then because of this interaction the ring structure must fall on the main galaxy disk very soon. Let us note also that inclined rings around spiral galaxies may be relatively stable only in the case when their diameters are larger than those of gaseous disks of main galaxies. ESO 235-58 (Buta & Crocker 1993) and NGC 660 (van Driel et al. 1995) are possible examples of such objects.

The formation of rings in NGC 3808B and NGC 6286 being accompanied by accretion of matter on galactic disks and interaction of two nearly orthogonal gaseous subsystems results in some interesting gasdynamical and stellardynamical effects in these galaxies. For instance, we may notice the peculiar rotation curve of NGC 3808B gaseous disk (see Fig.3b). Both galaxies demonstrate strong infra-red and Hα emission pointing to the high star-forming activity. Stellar disks of both galaxies increase their thickness when going from the center to periphery and are bended in the outlying regions. One can conclude that double systems similar to those considered in this paper are unique laboratories for studying effects of outer accretion on galaxy structure and evolution.

In conclusion let us pay attention to the fact that both NGC 3808B and NGC 6286 are viewed edge-on. It is such orientation that allows to include these in PRC, based on optical morphology. If NGC 3808B and NGC 6286 were observed at smaller angles to the line of sight, faint diffuse ring structures being projected onto the more bright regions of main galaxies would be indistinguishable and then the galaxies would not be included in PRC as candidates in PRGs. Undoubtedly, among double interacting galaxies other systems must exist which are similar to considered here but viewed by less advantageous angles for discovering the ring structures. For the search of such objects it would be interesting to undertake detail kinematic investigation of the sample of M 51-type galaxies (there are 160 such systems pointed out by Vorontsov-Velyaminov 1975).

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